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Development of a Dynamic Biomechanical Model for Load Carriage: Phase IV Part C4:

User's Manual for the Standardized Protocol of Mapping Skin Contact Pressure Using the Standardized Load Distribution Mannequin

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Abstract

The Dynamic Biomechanical Model (DBM) requires input about pack geometry and the material property response of the load carriage suspension interface to resolve the forces acting on the body. Since there is extensive redundancy in applied forces (i.e., shoulder straps, load lifter straps, hip stabilizer straps and waist belt and skin contact pressure), it is not possible to describe the mechanical characteristics of pack components as combinations of linear and/or non linear springs and linear and/or non linear dampers unless a standardized protocol is used to determine the limit values that should be placed on specific straps in the model. The purpose of this report is to describe the common pack protocol on the Load Distribution Mannequin that will be followed when establishing these limit values for the DBM. The rationale for using the static Load Distribution Mannequin is that forces can be partitioned into upper and lower body forces, it is easier to control strap force inputs than with the Load Carriage Simulator and dynamic forces follow a similar profile to static measures expect that amplitudes and phase shifts are likely. (DBM model is calibrated for these conditions using the LC Simulator). This report describes the protocol for the baseline testing of backpacks on the Standardized Load Distribution Mannequin (SLDM). The protocol describes three different configurations: isolated shoulder, isolated waist belt and combined shoulder and waist belt.

Résumé

Pour déterminer les forces exercées sur le corps, le modèle biomécanique dynamique (DBM) a besoin de données relatives à la géométrie du sac et à la réponse aux propriétés matérielles de l’interface de suspension de transport de charge. Étant donné qu’il existe une importante redondance des forces appliquées (sangles d’épaules, sangles de levage de charge, sangles de stabilisation au niveau des hanches et ceinture, et pression de contact avec la peau), il est impossible de décrire les caractéristiques mécaniques des composantes du sac sous forme de combinaisons de ressorts linéaires et/ou non linéaires et d’amortisseurs linéaires et/ou non linéaires, à moins d’utiliser un protocole normalisé pour déterminer les valeurs limites qui devraient être appliquées à des sangles particulières dans le modèle. Le présent rapport a pour objet de décrire le protocole de sac commun qui sera appliqué au mannequin à répartition de charge pour l’établissement des valeurs limites du DBM. On utilise le mannequin à répartition de charge statique pour les raisons suivantes : les forces peuvent être réparties en forces exercées sur la partie supérieure et sur la partie inférieure du corps, il est plus facile de régler les forces exercées par les sangles qu’avec le simulateur de transport de charge et les forces dynamiques suivent un profil similaire à celui des mesures statiques, sauf que les amplitudes et les déphasages sont semblables. (Le DBM est étalonné pour ces conditions à l’aide du simulateur de transport de charge). Le présent rapport décrit le protocole d’essai de base des sacs à dos sur le mannequin à répartition de charge normalisé (SLDM). Le protocole décrit trois configurations différentes : épaule isolée, ceinture isolée et épaule et ceinture combinées.

Executive Summary

Introduction

The shape of the human torso is very complex and, although we do have the 3D coordinates of the Load Carriage Simulator and Load Distribution Mannequin for dynamic biomechanical modeling, pressure measurement systems cannot be validated with it. This is because it is too difficult for the sensors to follow the contour of the body. To get around this problem, we developed a system that replaces the human-shaped Load Distribution Mannequin (LDM) The Standardized Torso consists of a shoulder mechanism (ABS pipe covered with Bocklite™) and a standardized lower torso (basswood covered with Bocklite™). In this way, sensors could be laid out in a smooth profile in order to develop a more accurate mapping function for forces on the shoulder and waist belt of a load carriage system. This information will be used as input to a dynamic biomechanical model.

Purpose

The purpose of this report is to write a User's Manual for testing with the Standardized Torso. In previous research by Hadcock et al (2002), this type of testing is needed to determine the input characteristics for each pack design tested, especially for various waist-belt designs.

Approach

This User's Manual is designed as a step by step guide for the protocol in using the Standardized Torso. The first section of the report describes the system components (shoulder and waist). The next phase of the report describes the coordinate system for each aspect as well as the supporting measurement tools that are needed. Then the calibration procedures are described. For each pack, the protocol requires a baseline data collection under empty conditions. Then loads are added to reflect the shoulder straps and waist belt's responses under different conditions. Lastly, a step by step processing with interconnected Excel spreadsheets is discussed. The execution of these correction factors and strap characteristics is processed in Excel and input into the dynamic biomechanical model.

Rationale for Approach

The Dynamic Biomechanical Model (DBM) requires input about pack geometry and material property response of the load carriage suspension interface to resolves the forces acting on the body. Since there is extensive redundancy in applied forces (i.e. shoulder straps, sternum strap, load lifter straps, hip stabilizer straps, waist belt) it is not possible to describe the mechanical characteristics of pack components as combinations of linear and/or non-linear springs and dampers unless a standardized protocol is used. This procedure will help determine the limit values that can be placed on various straps in the DBM. The rationale for using the LDM and the Standardized Torso is that the forces can be partitioned into upper and lower body forces because of the load cell at the waist (L3).

Sommaire

Introduction

La forme du torse humain est très complexe et, même si nous disposons des coordonnées 3D du simulateur de transport de charge et du mannequin à répartition de charge pour la modélisation biomécanique dynamique, nous ne pouvons pas nous en servir pour valider les systèmes de mesure de pression, car les capteurs sont incapables de suivre le contour du corps. Pour contourner ce problème, nous avons mis au point un système qui remplace le mannequin à répartition de charge (LDM) en forme de corps humain. Le torse normalisé consiste en un mécanisme d'épaule (tuyau en ABS recouvert de Bocklite^{MC}) et en une partie inférieure du torse normalisée (tilleul d'Amérique recouvert de Bocklite^{MC}). Il permet de disposer les capteurs suivant un profil régulier en vue d'établir une fonction de mappage plus précise pour les forces exercées sur l'épaule et la ceinture par un système de transport de charge. Ces données seront utilisées dans un modèle biomécanique dynamique.

Objet

Le présent rapport a pour objet de rédiger un manuel de l'utilisateur pour l'essai avec le torse normalisé. Dans des travaux de recherche précédents effectués par Hadcock et coll. (2002), ce type d'essai était nécessaire pour déterminer les caractéristiques d'entrée de chaque modèle de sac mis à l'essai, en particulier pour différents modèles de ceinture.

Méthode

Le présent manuel de l'utilisateur est conçu comme un guide étape par étape pour le protocole à suivre lorsqu'on utilise le torse normalisé. La première section du rapport décrit les composants du système (épaule et ceinture). La phase suivante décrit le système de coordonnées pour chaque aspect ainsi que les outils de mesure de soutien requis. La procédure d'étalonnage est ensuite décrite. L'application du protocole nécessite la collecte de données de base pour chaque sac vide. Des charges sont ensuite ajoutées pour refléter les réponses des sangles d'épaules et de la ceinture dans différentes conditions. Enfin, on présente un traitement étape par étape avec feuilles de calcul Excel interconnectées. L'application des facteurs de correction et des caractéristiques des sangles est effectuée en Excel, et les résultats sont utilisés dans le modèle biomécanique dynamique.

Justification de la méthode

Pour déterminer les forces exercées sur le corps, le modèle biomécanique dynamique (DBM) a besoin de données relatives à la géométrie du sac et à la réponse aux propriétés matérielles de l'interface de suspension de transport de charge. Étant donné qu'il existe une importante redondance des forces appliquées (sangles d'épaules, sangle de

sternum, sangles de levage de charge, sangles de stabilisation au niveau des hanches, ceinture), il est impossible de décrire les caractéristiques mécaniques des composants du sac sous forme de combinaisons de ressorts et d'amortisseurs linéaires et/ou non linéaires, à moins d'utiliser un protocole normalisé. Cette procédure aidera à déterminer les valeurs limites qui peuvent être appliquées à différentes sangles dans le DBM. L'utilisation du mannequin à répartition de charge et du torse normalisé se justifie par le fait que les forces peuvent être réparties en forces exercées sur la partie supérieure et sur la partie inférieure du corps, en raison de la présence de la cellule de charge à la ceinture (L3).

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1.0 Introduction

The Load Distribution Mannequin is a 50^{th} percentile male torso that has been modified at the waist to hold a six degree of freedom load cell at the level of L3 (waist). As part of an earlier contract to develop a waist belt model for the DBM, we designed and tested a Symmetrical Lower Torso (SLT) as a research tool for the development of the biomechanical model of the backpack (Hadcock, 2002a). Based on this research, Hadcock (2002b) concluded that different backpack designs have their own unique loading patterns and must be tested individually to determine the baseline characteristics under standardized loading in order to input the parameters into a mathematical model. In subsequent studies of pressure measurement systems by Morin, et al. (2003) and Stevenson, et al. (2003), it was realized that a similar standardized procedure for the shoulder would be helpful as well in modelling the DBM. As a result, a Standardized Shoulder (SS) form was created. Together these two parts form the new Standardized Load Distribution Mannequin(SLDM).

Based on the research of Hadcock et al. (2002 a,b) we realized that the F-Scan™ 9811 sensors by Tekscan were no longer appropriate for our needs. In earlier sections of this current contract report, we pointed out the poor reliability and validity of FScan™ and recommended selection of a different technology, namely the XSENSOR®™ Technology Corporation's X2 System. For ease of transition, this user's manual is prepared around the XSENSOR®™ as being the pressure measurement tool for use in development of the Dynamic Biomechanical Model.

This report describes the protocol for the baseline testing of backpacks on the SLDM. The protocol describes three different configurations: isolated shoulder, isolated waist belt and combined shoulder and waist belt. To account for curvature effects of the XSENSOR®™, each individual sensor needs to be calibrated for a specific location. It is recommended that it a new calibration file is created when any sensor is moved or used in a different application.

2.0 Description of System Components

2.1 General Overview

The Standardized Load Distribution Mannequin (SLDM) consists of a Standardized Lower Torso (SLT) (Hadcock 2002) and a Standardized Shoulder (SS) as in Figure 1. The shapes are symmetrical with known geometry. This known geometry allows for the measured surface pressures to be resolved into components in the X, Y and Z directions.

Figure 1. Standardized load distribution mannequin.

2.2 Symmetrical Lower Torso

The SLT is constructed with laminated basswood that was machined on a CNC lathe with further sanding and finishing performed by hand to remove any irregularities. The finished wood is covered with 3mm Bocklite™, a skin analog that provides slight surface compliance (Rigby and MacNeil, 1996). The Bocklite can be easily damaged and care must be taken not to gouge or rip the material. It can be marked with light pen or pencil if required.

A steel pipe is inserted into the bottom of the SLT and fit into an attachment on the base plate. The attachment mechanism allows for alteration of the lean angle of the torso. The lean angle can be adjusted by loosening the bolt underneath the attachment point as in Figure 2, and tightening the bolt when the SLT is at the desired angle. The base plate is designed to fit on top of the AMTI Force Plate, Model LG6-4-2000, with the centre axis of the SLT passing through the centre of the plate.

Figure 2. SLT Angle adjustment

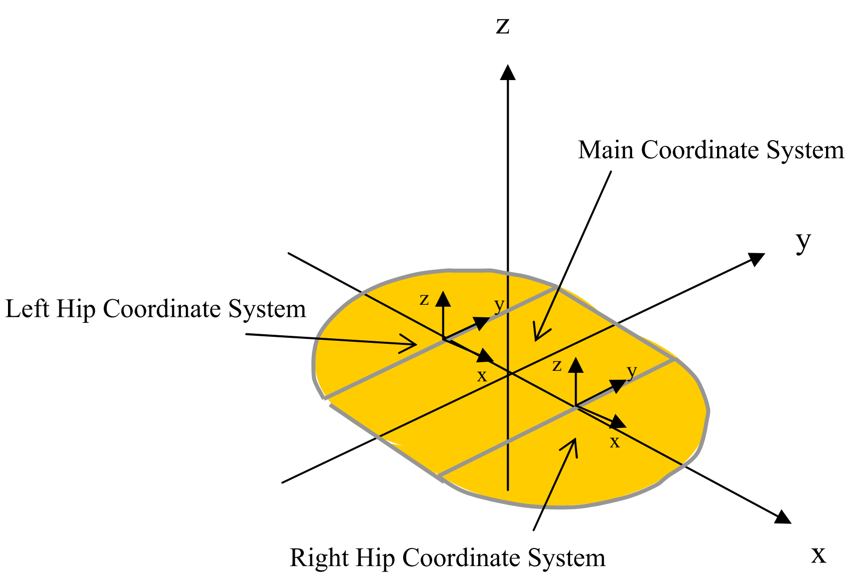

Figure 3. Coordinate system of the SLT.

Figure 3 shows the coordinate system for the pressure sensors on the SLT. Care was taken to orient the x,y,z axes of the pressure sensors on these same locations so that the semi-automated spreadsheets give the same results as this user's manual.

2.3 Standardized Shoulder

The design of the SS is based on MacNeil's (1996) shoulder model dimensions and materials. In the calibration routines used for the XSENSOR®™, the shoulder component is suspended with the weights hanging freely underneath. The SS is designed to sit on top of the SLT on the L3 six degree of freedom load cell. It must be anchored securely into position before SLDM testing. A 1.5" diameter ABS pipe is attached vertically to a centre post on the top of the SLT with piece of 4" ABS pipe covered in Bocklite horizontally at the top, creating a 'T'. An XSENSOR® is fastened to the horizontal piece to measure the pressures acting on the body from the shoulder straps. The geometry of the shoulder system provides contact only on the measurable surface of the shoulder by the shoulder straps, with no other upper body contact occurring. Sternum straps and load lifters can be used without contact in areas that are not measured by the system. The origin for calculations is considered to be the centre of the pipe. This allowed for ease of calculation of the surface normal vectors in two dimensions.

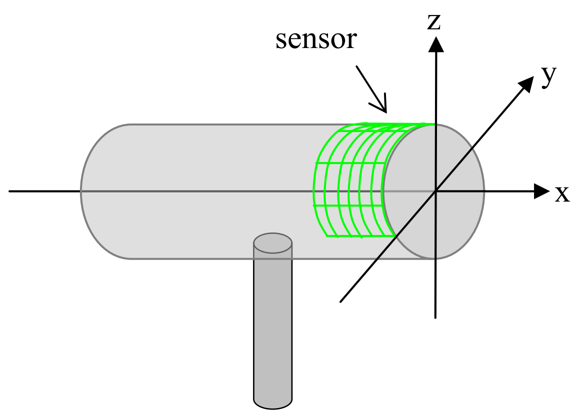

Figure 4. Coordinate system of the SS.

Based on the symmetry of the cylinder, the vector from the origin to the point of application of the force is the same as the surface normal vector. This vector is converted to a normal unit vector to resolve the measured force on the individual sensel.

Forces in the X direction are not measured by the system. They are assumed to be zero due to the shape of the shoulder model. The current sensor technology is incapable of measuring shear in the X direction. A six degree of freedom load cell mounted between the shoulder and lower torso model indicates any measured force in the X direction. For the purposes of this model the force in the X direction is assumed to be zero. If a force does exist, the load should be checked to make sure the forces are symmetrical on the right and left sides of the SS.

2.4 XSENSOR®

The pressure measurement system for this protocol is the capacitance-based X2 seat system, manufactured by XSENSOR® Technology Corporation. The pad is constructed of a non-trim, flexible urethane plastic that is pliable and detachable from the electronics. The X2 model uses a smart media card and a serial port for data transmission to the computer. The sensor pad

contains a 36 by 36 sensor arrangement, measuring 45.72cm by 45.72cm with a thickness of less than 1mm. The pad is composed of 1296 individual capacitive sensors and the system is capable of scanning all 1296 sensors on the pad at a rate of 30 scans per second. The recommended pressure range is 1.33-26.66 kPa. The system comes from the manufacturer pre-calibrated with software files. Consult the user's manual or the software for further information.

Figure 5. XSENSOR® X2 Seat Pad

2.5 Force transducer

The strap force transducers (Stevenson et al., 1996) consist of four strain gauges arranged in a full wheatstone bridge on a small aluminium 'dog-bone' shaped base as shown in Figure 6. Two other designs of the strain gauge transducers have been built during different contracts (Stevenson et al., 2001, Reid et al, 2002). These strap transducers are sewn or pinned into the webbing section of a waist belt or shoulder strap. These transducers have been shown to have a maximum standard error of between 1.5N and 2.6N for loads ranging from 44.5N to 177.5N. The data were highly linear with correlation coefficients of r^2 >0.99 (Stevenson, 1996). For further details on the use of the strap force transducers see the Load Carriage Simulator User's Manual (1998).

Figure 6. Strap force transducer.

2.6 Force Gauge

The Shimpo™ MF-100 push-pull gauge is a handheld force-measuring instrument. A bracket was designed to allow it to be linked in series with a 50.8 mm (2”) webbing strap to measure the tension in a strap. The gauge has a capacity of 445.9N (100lb) and has an analog dial measured in increments of 2.2N (0.5lb). The accuracy, specified by the manufacturer, is 0.2% full scale, or 0.9N (0.2lb) (www.shimpoinst.com). A simple calibration performed by suspending known masses from the gauge produced standard errors between 0.04N and 0.2N (0.01 and 0.05 lbs.). The errors for this gage were higher than the manufacturer specifications, perhaps due to reading of the gauge or setting the baseline load.

Figure 7. Force gauge.

2.7 In-Floor Force Plate

The model LG6-4-2000 (AMTI Incorporated, Boston, USA) force platform is built into the floor of the testing facility. The force platform measures forces and moments simultaneously in the X, Y and Z directions using four measurement gauges, one at each corner. The output voltages are proportional to the force applied to the system. The voltage signal is amplified with a Model SGA6-4 (AMTI Incorporated) and input to a National Instruments BNC-2090 connection box and sent through a 25-pin connector to an A/D board in the CPU of the computer. This signal is then captured using Labview Software (National Instruments Inc.).

The moments and forces acting on the lower body below the SLT are measured for each configuration and loading set-up. A calibration/zeroing file needs to be created for each set-up if the apparatus is moved on the force plate. The calibration/zeroing file negates the mass of the SLT and SS as well as the base plate. To record a calibration/zeroing file, follow the directions below.

1. Zero the empty force plate across all six channels.
2. Centre the baseplate of the apparatus on the force plate.
3. Collect one data set, 5 seconds at 50HZ to create a baseline file. The average of this data set is to be subtracted from each subsequent recoding while the apparatus is still in the same position. The calibration/zeroing file needs to be recalculated when the apparatus is moved or shifted.

2.8 Load Cell at Mid-section

The mid-section load cell is a six degree of freedom measurement device located at the level of T12/L1. The load cell is a MC5-6-2500 (AMTI Inc.), the output is amplified by a modular 600 multi-channel Transducer Conditioner (RDP Group) and acquired using a Keithly Metrabyte DAS 1200 A/D board and Viewdac on a Pentium PC. Refer to the manufacturers instruction manuals for further detailed information about the instrumentation and data acquisition system.

Calibration of Testing Apparatus

Pressure sensing technology has had mixed results on curved surfaces. This calibration procedure demonstrates to the user how well the system measures a known applied force. If the discrepancy of the measurements is larger than 10% the calculation of a coefficient of friction based on this procedure is necessary to apply to subsequent measurements made with the system. If the discrepancy is found to be less than 10%, a coefficient of friction does not need to be calculated.

3.1 Calibration of the SLT

The loading system is shown in Figure 8. A zero lean angle is used to maximize symmetry for initial testing. The calibration process is as follows:

1. Wrap the 10m length of 50.8mm (2”) wide webbing around the SLT and connect the end to the force gauge, as in Figure 8. Adjust the angle of the webbing to correspond to the slope of the SLT in order to maximise contact with the sensor and provide a normal force to the surface.
2. Place a piece of closed-cell foam underneath the webbing strap where it contacts the sensor. This reduces the effects of uneven tightening and the resulting line of pressure.
3. Attach the force gauge to a fixed object.
4. Slowly slide the SLT plate away from the force gauge to apply tension to the webbing. Block the plate from sliding back with weights or another suitable object. Apply a load between 25 and 100N. Ensure that the load is steady.

5. Record the applied pressure on the system.
6. Record 10 seconds worth of data on the XSENSOR®.
7. Check the reading on the force gauge to ensure the apparatus did not shift during the data recording. If it shifted, delete the trial and repeat.
8. Repeat the procedure for a total of ten different loads.
9. Input each XSENSOR® file to the SLT template, naming each trial with the date and trial number and the prefix ‘cal’.
10. The output on the first page of the template gives the resolved forces in the X, Y and Z directions. Input the force displayed on the force gauge to be converted into Newtons.
11. Discard any trials that have greater than 10% of the total applied force in the y-direction as this indicates that the testing apparatus was not symmetrical in the loading of the applied force.

The calibration spreadsheet calculates and minimizes the sum of the squared errors between the XSENSOR®™ forces and applied forces were using the coefficient of friction variable. The sensel forces are calculated, summed, and compared to the applied forces. The root mean square error (RMS) for each sensor is calculated as a measure of precision. For this calculation, the sum of squared errors for each sensor is divided by the number of trials.

$$RMS = \sqrt{\frac{SSE}{n}}$$

A) Top View

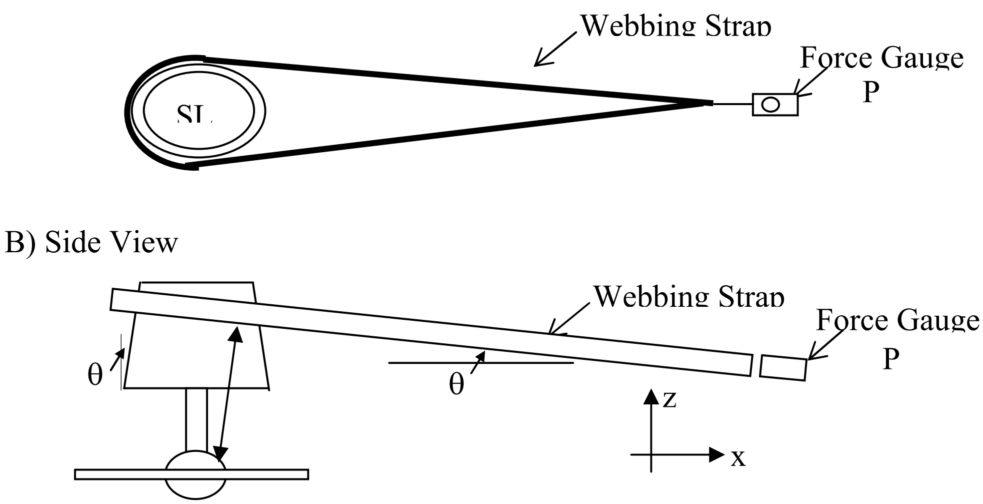

Figure 8. Calibration Set-up. Where F_x=Pcosθ, F_z=-Psinθ, and M_y=Pd.

4.0 Procedure for the Baseline Data Collection of a Backpack

The following procedures outline the complete collection of data using the isolated waist belt, isolated shoulder, and a combined complete pack-testing set-up. The complete pack set-up is sufficient for collection of baseline data and comparison of a design if the whole pack is to be analysed as a single unit. The isolated shoulder and waist belt procedures can be used if independent characteristics are required for analysis. The loading patterns for a full data set are as follows:

1. Empty
2. Light Load (e.g. 5 kg)
3. Medium Load (e.g. 10kg)
4. Heavy Load (e.g. 20kg)
5. Very Heavy (e.g. 30kg)

These loads should be applied in a random order. The pack should be placed on the apparatus in the same location for each trial of each load. Three trials should be performed for each load. The results are then averaged to provide one data set for each load for each pack tested.

4.1 Isolated Waist belt

4.1.1 Mounting of the Sensor

The first sensor should be placed, right side up, on the SLT with the top row corresponding with the upper edge of the lumbar or abdominal area. The line separating columns 18 and 19 should be centred in line with the midpoint on the upper edge of the lumbar or abdominal area. The second sensor should be placed directly opposite the first, as shown below.

Figure 9. XSENSOR®^{TM} placement on the SLT

4.1.2 Collection of Data

1. Affix the sensor to the SLT as in 'Mounting of the Sensor'.
2. Determine whether any overlap is occurring. If overlap is present, note which sensels are affected, in order to zero those sensels in data analysis. For example, if rows 30-36 are overlapped by rows 1-6, replace the measured values of data in rows 30-36 with zeroes in the raw data section of the spreadsheet.
3. Centre the apparatus on the AMTI force plate.
4. Record the calibration/zeroing file for the force plate. (5 seconds at 50Hz).
5. Zero the mid-section load cell.
6. Attach one strap force transducer on each side of the waist belt buckle of space permits. These two measurements will indicate the directional tightening effect, if any. Zero the two transducers (Reid, 1998).
7. Place the backpack waist belt on the SLT and fasten it with the top approximately 10cm from the top of the sensor. Tension the belt to approximately 50N on each transducer.
8. Hook the force gauge into the lifting handle at the top of the pack. This handle should be on the top of the pack suspension facing forwards. Support the pack horizontally with the force gauge, as in Figure 10.
9. Record the measured force from the force gauge.
10. Record the measured forces from the strap force transducers.
11. Record the measured forces from the AMTI force plate.
12. Record the measured forces with the mid-section load cell.
13. Record the trial with the XSENSOR® software

Figure 10. Pack placement for isolated waist belt testing.

14. Save the file as an XSENSOR® file as backup and export the data as a ‘text’ files, average of all points. (File>Export>Average of all points>Add interval (all points)>Save as ASCII)
15. Unload the SLT and repeat the procedure a minimum of three times per load to average the results.
16. Open the ‘XSENSOR® SLT Template (vFeb7).xls’ file and save it under a new file name – using the testing date in the new name is recommended, e.g. ‘Jan14-03XSENSOR® SLTTest1’.
17. Open the text file for the first trial into Excel. Press ‘finish’, as the default settings are correct.
18. Copy the values in the 36 columns and rows. Do not copy headers.
19. Paste special (‘Values’) into the worksheet labelled “Raw Data Input - Trial 1”.
20. If any overlap occurred during testing, change the corresponding values to zeros in the raw data.
21. The worksheet “Output - Trial 1” outputs the values as X, Y, and Z values and converts them to Newtons. The raw sum, with no curvature effects, is shown for comparison.

4.2 Isolated Shoulder

4.2.1 Mounting of the Sensor

Place the sensor, right side up on the shoulder tube, as in Figure 11. The origin should be in the position shown below. The middle of the sensor, between rows 18 and 19 should lie along the top of the tube. The sensor should be taped in place along the ends.

If overlapping occurs, the overlap areas must be taken into consideration when the data is analysed. The overlapping area must be zeroed in the collected data, as including it will create redundancy and inaccurate results.

Figure 11. XSENSOR® placement on the SS.

4.2.2 Collection of Data

1. Affix the sensor to the shoulder as in 'Mounting of the Sensor'. Determine whether any overlap is occurring. If overlap is present, note which sensels are affected, in order to zero those sensels in data analysis. For example, if rows 30-36 are overlapped by rows 1-6, replace the measured values of data in rows 30-36 with zeroes in the raw data section of the spreadsheet.
2. Measure the mass of the pack.
3. Attach a force transducer to each shoulder strap in the thin webbing, below the shoulder padding and above the attachment to the base of the pack. Zero the transducers once they are attached to the strap (Reid, 1998).
4. Centre the apparatus on the AMTI force plate.
5. Record a calibration/zeroing file from the force plate.

6. Zero the mid-section load cell.
7. Place the backpack on the apparatus with the shoulder straps at a length that places the lumbar pad of the backpack on the flat lumbar area of the SLT. This placement provides a standard for each pack to be tested.
8. The waist belt should be fastened around the back of the pack or removed if it is independent of the lumbar pad. There should be no contact of the pack on the SLT other than the flat lumbar area, as in Figure 12.
9. Settle the pack by shaking the plate with the handle.
10. Record the AMTI force plate measurements (5 seconds at 50Hz).

Figure 12. Pack placement for isolated shoulder testing.

11. Record the mid-section load cell measurements.
12. Record the strap tension.
13. Record the XSENSOR® output.
14. Save the file as an XSENSOR® file as backup and export the data as a 'text' files, average of all points. (File>Export>Average of all points>Add interval (all points)>Save as ASCII).
15. Remove the pack and repeat the procedure a minimum of three times per load to average the results.
16. Open the 'XSENSOR® Shoulder Template' file and save it under a new file name – using the testing date in the new name is recommended.
17. Open the text file for the first trial into Excel. Press 'finish', as the default settings are correct.
18. Copy the values in the 36 columns and rows. Do not copy headers.
19. Paste special ('Values') into the worksheet labelled "Trial 1 - raw'.

20. If any overlap occurred during testing, change the corresponding values to zeros in the raw data.
21. The worksheet "Trial 1" outputs the values as X, Y, and Z values and converts them to Newtons. The raw sum, with no curvature effects, is shown for comparison.

4.3 Combined Waist belt and Shoulder

4.3.1 Mounting of the sensors

The sensors should be mounted as in the previous sections for isolated data collection.

4.3.2 Data Acquisition

1. Centre the empty apparatus on the AMTI force plate.
2. Record a calibration/zeroing file on the force plate (5 seconds at 50Hz).
3. Zero the mid-section load cell.
4. Place the empty or loaded pack on the apparatus.
5. Tighten the shoulder straps to position the midline of the waist belt approximately 20cm below the upper edge of the SLT, as in figure 4.5.
6. Tension the waist belt to the desired tension, generally 50N.
7. Settle the pack by shaking the plate with the handle.
8. Make minor adjustments to the waist belt tension if it has reduced/increased significantly.
9. Record the AMTI force plate measurements.
10. Record the mid-section load cell measurements.
11. Record the strap tension from each of the transducers.
12. Record the XSENSOR® output.
13. Save the SS and SLT files as XSENSOR® files as backup and export the data as 'text' files, average of all points. (File>Export>Average of all points>Add interval (all points)>Save as ASCII).
14. Remove the pack and repeat the procedure a minimum of three times per load to average the results.
15. Open the 'XSENSOR® Shoulder Template (v.Feb7).xls' file and save it under a new file name – using the testing date in the new name is recommended.
16. Open the text file for the first trial into Excel. Press 'finish', as the default settings are correct.
17. Copy the values in the 36 columns and rows. Do not copy headers.
18. Paste special ('Values') into the worksheet labelled "Trial 1 - raw'.
19. If any overlap occurred during testing, change the corresponding values to zeros in the raw data.
22. The worksheet "Trial 1" outputs the values as X, Y, and Z values and converts them to Newtons. The raw sum, with no curvature effects, is shown for comparison.
23. Open the 'XSENSOR® SLT Template (vFeb7).xls' file and save it under a new file name – using the testing date in the new name is recommended, e.g. 'Jan14-03XSENSOR® SLTTest1'.
24. Open the text file for the first trial into Excel. Press 'finish' as the default settings are correct.
25. Copy the values in the 36 columns and rows. Do not copy headers.

26. Paste special (‘Values’) into the worksheet labelled “Raw Data Input - Trial 1”.
27. If any overlap occurred during testing, change the corresponding values to zeros in the raw data.
28. The worksheet “Output - Trial 1” outputs the values as X, Y, and Z values and converts them to Newtons. The raw sum, with no curvature effects, is shown for comparison.

Data Reduction and Comparison

The output from the SS and SLT template spreadsheets produces the average measured force for each configuration in the X, Y and Z directions. The X direction in the isolated shoulder configuration is considered to be zero. Several comparisons can be made when the three configurations are input to the final spreadsheet template (‘Final XSENSOR® SLDM Template.xls’):

- The values of the averaged measured forces with the measured strap forces
- The ratio of shoulder and waist belt vertical forces (Z-direction) for each configuration
- The moment created by the forces acting on the shoulder and lower torso

1. Open the file ‘Final XSENSOR® SLDM Template’, save the file with a name that corresponds to the testing date and the pack name or number.
2. Input the date and the pack name in the upper left corner of the spreadsheet.
3. Input the loads, in kg, of each of the average trials for the SS, SLT and combined trials in the designated cells.
4. To input SS values to the final spreadsheet, ‘paste special’ the averaged values in cells B17 through D17 from the SS summary page into cells D13 through F13. Repeat for each of the different loads.
5. To input SLT values to the final spreadsheet, ‘paste special’ the averaged values in cells B14 though D14 from the SLT summary page into cells D6 though F6.
6. To input the combined values to the final spreadsheet, ‘paste special’ the averaged values in cells B17 though D17 from the SS summary page and cells B14 through D14 from the SLT summary page into the corresponding cells. Repeat for each of the different loads.
7. Input the lean angle into the corresponding cell, input a zero if the SLDM was vertical.
8. Input the measured strap tensions in Newtons to the corresponding cells.
9. The spreadsheet automatically calculates the expected forces acting on the SS and SLT using the load in the pack.
10. The spreadsheet automatically calculates the ratio between shoulder and waist load and the moment acting about the waist (top of SLT) for the combined SS and SLT trials. The moment arms for calculation are considered to be the distance from the midpoint of the shoulder in the Z-direction and the point 10cm below the top of the SLT.
    Graphic output from the XSENSOR® can be printed and compared for each waist belt and shoulder harness. The graphic displays allow for any peak or point pressures to be located. The data from the AMTI force plate and the mid-section load cell can be directly compared between loads on a pack or compared for the same configuration on different packs.

6.0 Conclusion – Future Work

The standardized load distribution mannequin has a multitude of future applications. The effects of load placement locations on surface pressure can be compared. Different materials such as padding and covering cloth can be examined and compared. The effect of the order of tightening of straps can be quantified for individual packs. Dynamic testing can be performed with an appropriate pressure sensing technology with adjustments for amplitude and potential phase shift.

7.0 References

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MacNeil S.K. (1996). *Validation and development of a mathematical model of the shoulder for load carriage*. Master's thesis. Queen's University, Canada.

MacNeil, S.K., Rigby, W.A. (1996) Determination of an appropriate substitute skin. Queen's University, Kingston, ON. (Unpublished).

Reid, S.A., User's Manual: Load Carriage Simulator V1.02, Ergonomics Research Group, Queen's University (Unpublished), October 1998.

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Stevenson, J.M., Reid, S.A., Bryant, J.T., Hadcock, L.J., Morin, E,L. (2001). Development of a Dynamic Biomechanical Model for Load carriage Phase I: *Part A: Equipment Upgrade to Accommodate Dynamic Biomechanical Modeling.* PWGSC Contract No. W7711-0-7632/A Report to the Defence Research and Development Canada.

Reid, S.A., Saunders, G.A.B., Good, J.A., Bryant, J.T., Stevenson, J.M. (2001). Development of a Dynamic Biomechanical Model for Load Carriage Phase 2: *Initial Development of a Novel Strap Tension Sensor.* PWGSC Contract No. W7711-0-7632/A Report to the Defence Research and Development Canada.

User's manual: Xsensor X2 Seat Pad (2002), Xsensor Technology Corporation.

Appendix A

SS Model Spreadsheet: ‘XSENSOR® SLT Template (v.Feb7).xls’

Summary of Trial Output

Results copied from individual output sheets - Do not modify this sheet
Measured: Values output from sensor and resolved with normal values
Expected: Forces applied during calibration with force gauge (Input on 'Output' Sheets)
Ratios: Indication of how measured and expected values compare

	Measured (N)			Expected (N)		
	X	Y	Z	X	Y	Z
Trial 1	-1.400076	111.3169	-20.89814	0	83.69371	-11.76238
Trial 2	2.786334	96.40396	-17.7528	0	83.69371	-11.76238
Trial 3	-3.889267	77.63732	-14.10468	0	83.69371	-11.76238

Ratio (MeasY/ExpY)	Ratio MeasZ/ExpZ
1.330051348	1.776692948
1.151866207	1.509285775
0.927636196	1.199134164

Average	-0.834336	95.1194	-17.58521

Xsensor raw data (mmHg)

INPUT RAW DATA HERE

Row \ Column	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
1	0	0	0	0	0	0	0	0	0	0	0	0	0	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	39	39	36	31	28	26	24	23	20	18	20	16	0	0	0	0	0	0	0	22	20	19	20	20	24	22	25	25	27	33	27	0	0
6	0	0	43	147	121	100	98	83	77	72	69	55	55	59	51	26	0	0	9	0	0	32	54	47	50	59	53	59	69	72	72	77	102	97	45	0
7	0	0	99	147	147	147	147	147	147	147	147	147	147	148	147	97	18	15	17	11	25	146	147	147	147	147	146	147	146	146	146	147	147	147	111	0
8	0	0	0	0	0	0	0	0	10	15	23	25	29	36	33	24	0	0	0	0	0	25	29	24	21	19	14	11	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

3574 3394

This Section for Calibration/Validation Only - Input into blue and yellow cells				
Angle of applied force from horizontal	8	degrees		
Applied force (measured from Shimpo	19	lb		
	X	Y	Z	
Resolved Applied Force (Newtons)	0	83.7	-11.762	

Force Per Sensel

Column

Row	1			2			3			4			5			6			7			8			9			10			11			12			13			14			15			16			17			18		
	X	Y	Z	X	Y	Z	X	Y	Z	X	Y	Z	X	Y	Z	X	Y	Z	X	Y	Z	X	Y	Z	X	Y	Z	X	Y	Z	X	Y	Z	X	Y	Z	X	Y	Z	X	Y	Z	X	Y	Z	X	Y	Z	X	Y	Z	X	Y	Z
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	15	2	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	7.93	4.1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	36	15	5	34	18	5	29	20	5	23	20.2	4	19	20	4	15	21	4	12	21	3	9	21	3	5	19	3	3	17.5	3	2	20	3	0	16	2	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	41	13	6	134	58	20	104	59	17	80	59	14	72	65.2	14	55	61	12	43	63	11	34	63	10	25	63	10	13	53	8	9	53.7	8	5	58	8	0	51	7	0	26	4	0	0	0	0	0	0
7	0	0	0	0	0	0	93	31	14	132	61	20	125	74	20	115	89	20	106	99.8	20	95	111	20	80	122	20	66	130	20	52	136	20	33	142	20	22	144	20	11	146	21	0	146	20	0	96	13	0	18	3	0	15	2
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5.3	8.39	1	6.5	13	2	8	21	3	5	24	3	4	28.4	4	2	36	5	0	33	5	0	24	3	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
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Column Totals	0	0	0	0	0	0	134	44	20	302	133	46	271	156	44	224	168	39	201	185	38	168	192	36	143	214	36	118	227	36	94	242	36	57	238	34	38	244	35	22	274	39	0	245	34	0	146	20	0	18	3	0	15	2

Totals	X	Y	Z
	-65.1	5177	-971.85
Newtons	-1.4	111	-20.898

This sheet contains the normal vectors: L,M,N for each sensel
These values are multiplied by the measured raw force on the Output worksheets

Column 1			Col2			col 3			col 4			col 5			col 6			col 7			col 8			col 9			col 10		
-0.01519	0.051827	0.139173	0.988204	0.063904	0.139173	0.97431	0.177062	0.139173	0.946998	0.289526	0.139173	0.907445	0.396453	0.139173	0.854993	0.499618	0.139173	0.791902	0.594577	0.139173	0.717124	0.682908	0.139173	0.63388	0.760807	0.139173	0.540787	0.829566	0.139173
-0.01052	0.025913	0.139173	0.986348	0.088029	0.139173	0.969693	0.200814	0.139173	0.940727	0.309295	0.139173	0.898943	0.41537	0.139173	0.844342	0.517414	0.139173	0.780342	0.60967	0.139173	0.706309	0.694088	0.139173	0.619158	0.772835	0.139173	0.526227	0.838878	0.139173
0.99999	0	0.139173	0.983705	0.113819	0.139173	0.964888	0.222762	0.139173	0.933468	0.330558	0.139173	0.890047	0.434105	0.139173	0.833321	0.534983	0.139173	0.769583	0.623196	0.139173	0.694088	0.706309	0.139173	0.604207	0.784579	0.139173	0.511506	0.847934	0.139173
0.989476	0.025921	0.139173	0.980631	0.137819	0.139173	0.959157	0.24627	0.139173	0.925728	0.351651	0.139173	0.880761	0.452649	0.139173	0.821935	0.552317	0.139173	0.757477	0.637855	0.139173	0.681656	0.718315	0.139173	0.589034	0.796034	0.139173	0.49663	0.856732	0.139173
0.984808	0.051827	0.139173	0.976687	0.163441	0.139173	0.952854	0.26963	0.139173	0.917512	0.372563	0.139173	0.871088	0.470995	0.139173	0.810188	0.569409	0.139173	0.74623	0.650978	0.139173	0.670289	0.728933	0.139173	0.573644	0.807195	0.139173	0.481602	0.865269	0.139173
0.987215	0.077696	0.139173	0.972074	0.188952	0.139173	0.945982	0.29283	0.139173	0.908823	0.393283	0.139173	0.861885	0.487631	0.139173	0.798085	0.586252	0.139173	0.733595	0.665183	0.139173	0.657465	0.740521	0.139173	0.558042	0.818059	0.139173	0.466428	0.873542	0.139173
0.984843	0.103511	0.139173	0.967167	0.212646	0.139173	0.939095	0.314217	0.139173	0.900387	0.41223	0.139173	0.851484	0.505574	0.139173	0.785632	0.602837	0.139173	0.72069	0.679144	0.139173	0.644441	0.751882	0.139173	0.542234	0.828621	0.139173	0.451112	0.881549	0.139173
0.981796	0.129256	0.139173	0.96127	0.23789	0.139173	0.931137	0.337067	0.139173	0.890803	0.432551	0.139173	0.84071	0.523296	0.139173	0.772835	0.619158	0.139173	0.708728	0.691618	0.139173	0.632551	0.761912	0.139173	0.526227	0.838878	0.139173	0.435658	0.889288	0.139173
0.978076	0.154912	0.139173	0.954713	0.262972	0.139173	0.922624	0.359716	0.139173	0.880761	0.452649	0.139173	0.829566	0.540787	0.139173	0.759699	0.635207	0.139173	0.69532	0.705097	0.139173	0.619158	0.772835	0.139173	0.510026	0.848825	0.139173	0.420071	0.896756	0.139173
0.973686	0.180462	0.139173	0.948003	0.286219	0.139173	0.91356	0.38215	0.139173	0.870265	0.472515	0.139173	0.818059	0.558042	0.139173	0.74623	0.650978	0.139173	0.681656	0.718315	0.139173	0.605576	0.783523	0.139173	0.493636	0.85846	0.139173	0.404357	0.903951	0.139173
0.968628	0.205888	0.139173	0.940186	0.310937	0.139173	0.904655	0.402778	0.139173	0.85932	0.492137	0.139173	0.806193	0.575052	0.139173	0.732433	0.666463	0.139173	0.669015	0.730102	0.139173	0.593194	0.792939	0.139173	0.477065	0.867779	0.139173	0.388519	0.91087	0.139173
0.962907	0.231173	0.139173	0.931724	0.335441	0.139173	0.894544	0.424761	0.139173	0.848825	0.510026	0.139173	0.793973	0.591809	0.139173	0.718315	0.681656	0.139173	0.654876	0.742811	0.139173	0.579265	0.803171	0.139173	0.460318	0.876777	0.139173	0.372563	0.917512	0.139173
0.956526	0.2563	0.139173	0.92325	0.358105	0.139173	0.883899	0.44649	0.139173	0.837036	0.529152	0.139173	0.781405	0.608307	0.139173	0.702665	0.697777	0.139173	0.641812	0.754127	0.139173	0.565159	0.813158	0.139173	0.443402	0.885452	0.139173	0.35488	0.924495	0.139173
0.949489	0.281251	0.139173	0.91356	0.38215	0.139173	0.873542	0.466428	0.139173	0.824815	0.548006	0.139173	0.768494	0.624538	0.139173	0.687898	0.712339	0.139173	0.627217	0.766309	0.139173	0.550882	0.822897	0.139173	0.426321	0.893801	0.139173	0.338692	0.930548	0.139173
0.941801	0.30601	0.139173	0.903951	0.404357	0.139173	0.861885	0.487631	0.139173	0.81217	0.566578	0.139173	0.756363	0.639176	0.139173	0.672829	0.726589	0.139173	0.61239	0.778209	0.139173	0.537888	0.831449	0.139173	0.409084	0.901821	0.139173	0.3224	0.936317	0.139173
0.933468	0.330558	0.139173	0.893056	0.427881	0.139173	0.849714	0.508544	0.139173	0.799107	0.584858	0.139173	0.742811	0.654876	0.139173	0.657465	0.740521	0.139173	0.598715	0.788778	0.139173	0.523296	0.84071	0.139173	0.391696	0.909508	0.139173	0.30601	0.941801	0.139173
0.924495	0.35488	0.139173	0.881549	0.451112	0.139173	0.837036	0.529152	0.139173	0.786683	0.601465	0.139173	0.728933	0.670289	0.139173	0.641812	0.754127	0.139173	0.583462	0.800127	0.139173	0.508544	0.849714	0.139173	0.374164	0.91686	0.139173	0.289526	0.946998	0.139173
0.914888	0.378959	0.139173	0.870265	0.472515	0.139173	0.824815	0.548006	0.139173	0.772835	0.619158	0.139173	0.714736	0.685407	0.139173	0.625878	0.767403	0.139173	0.569409	0.810188	0.139173	0.495134	0.857597	0.139173	0.356493	0.923874	0.139173	0.272955	0.951907	0.139173
0.904655	0.402778	0.139173	0.857597	0.495134	0.139173	0.81118	0.567994	0.139173	0.758589	0.636532	0.139173	0.700225	0.700225	0.139173	0.60967	0.780342	0.139173	0.553751	0.820969	0.139173	0.480091	0.866108	0.139173	0.35488	0.924495	0.139173	0.2563	0.956526	0.139173

col 11			col 12			col 13			col 14			col 15			col 16			col 17			col 18			col 19			col 20		
0.441855	0.886225	0.139173	0.335441	0.931724	0.139173	0.226129	0.964104	0.139173	0.112102	0.983902	0.139173	3E-15	0.990268	0.139173	3E-15	0.990268	0.139173	3E-15	0.990268	0.139173	3E-15	0.990268	0.139173	-3E-15	0.990268	0.139173	-3E-15	0.990268	0.139173
0.427881	0.893056	0.139173	0.317493	0.937992	0.139173	0.214333	0.966795	0.139173	0.106948	0.984476	0.139173	3E-15	0.990268	0.139173	3E-15	0.990268	0.139173	3E-15	0.990268	0.139173	3E-15	0.990268	0.139173	-3E-15	0.990268	0.139173	-3E-15	0.990268	0.139173
0.4138	0.899667	0.139173	0.299427	0.943914	0.139173	0.200814	0.969693	0.139173	0.100073	0.985199	0.139173	3E-15	0.990268	0.139173	3E-15	0.990268	0.139173	3E-15	0.990268	0.139173	3E-15	0.990268	0.139173	-3E-15	0.990268	0.139173	-3E-15	0.990268	0.139173
0.398036	0.906751	0.139173	0.281251	0.949489	0.139173	0.188952	0.972074	0.139173	0.094913	0.985709	0.139173	3E-15	0.990268	0.139173	3E-15	0.990268	0.139173	3E-15	0.990268	0.139173	3E-15	0.990268	0.139173	-3E-15	0.990268	0.139173	-3E-15	0.990268	0.139173
0.383744	0.912892	0.139173	0.262972	0.954713	0.139173	0.177062	0.97431	0.139173	0.088029	0.986348	0.139173	3E-15	0.990268	0.139173	3E-15	0.990268	0.139173	3E-15	0.990268	0.139173	3E-15	0.990268	0.139173	-3E-15	0.990268	0.139173	-3E-15	0.990268	0.139173
0.369358	0.918807	0.139173	0.244595	0.959585	0.139173	0.163441	0.976687	0.139173	0.081141	0.986938	0.139173	3E-15	0.990268	0.139173	3E-15	0.990268	0.139173	3E-15	0.990268	0.139173	3E-15	0.990268	0.139173	-3E-15	0.990268	0.139173	-3E-15	0.990268	0.139173
0.35488	0.924495	0.139173	0.226129	0.964104	0.139173	0.151497	0.978611	0.139173	0.075972	0.98735	0.139173	3E-15	0.990268	0.139173	3E-15	0.990268	0.139173	3E-15	0.990268	0.139173	3E-15	0.990268	0.139173	-3E-15	0.990268	0.139173	-3E-15	0.990268	0.139173
0.340315	0.929955	0.139173	0.207579	0.968268	0.139173	0.13953	0.980389	0.139173	0.069078	0.987856	0.139173	3E-15	0.990268	0.139173	3E-15	0.990268	0.139173	3E-15	0.990268	0.139173	3E-15	0.990268	0.139173	-3E-15	0.990268	0.139173	-3E-15	0.990268	0.139173
0.325666	0.935186	0.139173	0.188952	0.972074	0.139173	0.125828	0.982241	0.139173	0.062179	0.988314	0.139173	3E-15	0.990268	0.139173	3E-15	0.990268	0.139173	3E-15	0.990268	0.139173	3E-15	0.990268	0.139173	-3E-15	0.990268	0.139173	-3E-15	0.990268	0.139173
0.309295	0.940727	0.139173	0.170256	0.975522	0.139173	0.113819	0.983705	0.139173	0.057004	0.988626	0.139173	3E-15	0.990268	0.139173	3E-15	0.990268	0.139173	3E-15	0.990268	0.139173	3E-15	0.990268	0.139173	-3E-15	0.990268	0.139173	-3E-15	0.990268	0.139173
0.294481	0.945469	0.139173	0.151497	0.978611	0.139173	0.101792	0.985022	0.139173	0.050101	0.989	0.139173	3E-15	0.990268	0.139173	3E-15	0.990268	0.139173	3E-15	0.990268	0.139173	3E-15	0.990268	0.139173	-3E-15	0.990268	0.139173	-3E-15	0.990268	0.139173
0.279594	0.949978	0.139173	0.132682	0.981339	0.139173	0.088029	0.986348	0.139173	0.043195	0.989326	0.139173	3E-15	0.990268	0.139173	3E-15	0.990268	0.139173	3E-15	0.990268	0.139173	3E-15	0.990268	0.139173	-3E-15	0.990268	0.139173	-3E-15	0.990268	0.139173
0.264638	0.954252	0.139173	0.113819	0.983705	0.139173	0.075972	0.98735	0.139173	0.038014	0.989538	0.139173	3E-15	0.990268	0.139173	3E-15	0.990268	0.139173	3E-15	0.990268	0.139173	3E-15	0.990268	0.139173	-3E-15	0.990268	0.139173	-3E-15	0.990268	0.139173
0.249616	0.958291	0.139173	0.094913	0.985709	0.139173	0.063904	0.988204	0.139173	0.031105	0.989779	0.139173	3E-15	0.990268	0.139173	3E-15	0.990268	0.139173	3E-15	0.990268	0.139173	3E-15	0.990268	0.139173	-3E-15	0.990268	0.139173	-3E-15	0.990268	0.139173
0.234533	0.962094	0.139173	0.075972	0.98735	0.139173	0.050101	0.989	0.139173	0.025922	0.989929	0.139173	3E-15	0.990268	0.139173	3E-15	0.990268	0.139173	3E-15	0.990268	0.139173	3E-15	0.990268	0.139173	-3E-15	0.990268	0.139173	-3E-15	0.990268	0.139173
0.217707	0.966041	0.139173	0.057004	0.988626	0.139173	0.038014	0.989538	0.139173	0.019011	0.990086	0.139173	3E-15	0.990268	0.139173	3E-15	0.990268	0.139173	3E-15	0.990268	0.139173	3E-15	0.990268	0.139173	-3E-15	0.990268	0.139173	-3E-15	0.990268	0.139173
0.202506	0.969341	0.139173	0.038014	0.989538	0.139173	0.025922	0.989929	0.139173	0.012098	0.990194	0.139173	3E-15	0.990268	0.139173	3E-15	0.990268	0.139173	3E-15	0.990268	0.139173	3E-15	0.990268	0.139173	-3E-15	0.990268	0.139173	-3E-15	0.990268	0.139173
0.187255	0.972402	0.139173	0.001728	0.990267	0.139173	0.012098	0.990194	0.139173	0.006913	0.990244	0.139173	3E-15	0.990268	0.139173	3E-15	0.990268	0.139173	3E-15	0.990268	0.139173	3E-15	0.990268	0.139173	-3E-15	0.990268	0.139173	-3E-15	0.990268	0.139173
0.171958	0.975224	0.139173	3.36E-15	0.990268	0.139173	3.36E-15	0.990268	0.139173	3.36E-15	0.990268	0.139173	3E-15	0.990268	0.139173	3E-15	0.990268	0.139173	3E-15	0.990268	0.139173	3E-15	0.990268	0.139173	-3E-15	0.990268	0.139173	-3E-15	0.990268	0.139173

col 21			col 22			col 23			col 24			col 25			col 26			col 27			col 28			col 29			col 30		
-3E-15	0.990268	0.139173	-3E-15	0.990268	0.139173	-0.1121	0.983902	0.139173	-0.22613	0.964104	0.139173	-0.33544	0.931724	0.139173	-0.44186	0.886225	0.139173	-0.54079	0.829566	0.139173	-0.63388	0.760807	0.139173	-0.71712	0.682908	0.139173	-0.7919	0.594577	0.139173
-3E-15	0.990268	0.139173	-3E-15	0.990268	0.139173	-0.10695	0.984476	0.139173	-0.21433	0.966795	0.139173	-0.31749	0.937992	0.139173	-0.42788	0.893056	0.139173	-0.52623	0.838878	0.139173	-0.61916	0.772835	0.139173	-0.70631	0.694088	0.139173	-0.78034	0.60967	0.139173
-3E-15	0.990268	0.139173	-3E-15	0.990268	0.139173	-0.10007	0.985199	0.139173	-0.20081	0.969693	0.139173	-0.29943	0.943914	0.139173	-0.4138	0.899667	0.139173	-0.51151	0.847934	0.139173	-0.60421	0.784579	0.139173	-0.69409	0.706309	0.139173	-0.76958	0.623196	0.139173
-3E-15	0.990268	0.139173	-3E-15	0.990268	0.139173	-0.09491	0.985709	0.139173	-0.18895	0.972074	0.139173	-0.28125	0.949489	0.139173	-0.39804	0.906751	0.139173	-0.49663	0.856732	0.139173	-0.58903	0.796034	0.139173	-0.68166	0.718315	0.139173	-0.75748	0.637855	0.139173
-3E-15	0.990268	0.139173	-3E-15	0.990268	0.139173	-0.08803	0.986348	0.139173	-0.17706	0.97431	0.139173	-0.26297	0.954713	0.139173	-0.38374	0.912892	0.139173	-0.4816	0.865269	0.139173	-0.57364	0.807195	0.139173	-0.67029	0.728933	0.139173	-0.74623	0.650978	0.139173
-3E-15	0.990268	0.139173	-3E-15	0.990268	0.139173	-0.08114	0.986938	0.139173	-0.16344	0.976687	0.139173	-0.2446	0.959585	0.139173	-0.36936	0.918807	0.139173	-0.46643	0.873542	0.139173	-0.55804	0.818059	0.139173	-0.65746	0.740521	0.139173	-0.7336	0.665183	0.139173
-3E-15	0.990268	0.139173	-3E-15	0.990268	0.139173	-0.07597	0.98735	0.139173	-0.1515	0.978611	0.139173	-0.22613	0.964104	0.139173	-0.35488	0.924495	0.139173	-0.45111	0.881549	0.139173	-0.54223	0.828621	0.139173	-0.64444	0.751882	0.139173	-0.72069	0.679144	0.139173
-3E-15	0.990268	0.139173	-3E-15	0.990268	0.139173	-0.06908	0.987856	0.139173	-0.13953	0.980389	0.139173	-0.20758	0.968268	0.139173	-0.34032	0.929955	0.139173	-0.43566	0.889288	0.139173	-0.52623	0.838878	0.139173	-0.63255	0.761912	0.139173	-0.70873	0.691618	0.139173
-3E-15	0.990268	0.139173	-3E-15	0.990268	0.139173	-0.06218	0.988314	0.139173	-0.12583	0.982241	0.139173	-0.18895	0.972074	0.139173	-0.32567	0.935186	0.139173	-0.42007	0.896756	0.139173	-0.51003	0.848825	0.139173	-0.61916	0.772835	0.139173	-0.69532	0.705097	0.139173
-3E-15	0.990268	0.139173	-3E-15	0.990268	0.139173	-0.057	0.988626	0.139173	-0.11382	0.983705	0.139173	-0.17026	0.975522	0.139173	-0.3093	0.940727	0.139173	-0.40436	0.903951	0.139173	-0.49364	0.85846	0.139173	-0.60558	0.783523	0.139173	-0.68166	0.718315	0.139173
-3E-15	0.990268	0.139173	-3E-15	0.990268	0.139173	-0.0501	0.989	0.139173	-0.10179	0.985022	0.139173	-0.1515	0.978611	0.139173	-0.29448	0.945469	0.139173	-0.38852	0.91087	0.139173	-0.47707	0.867779	0.139173	-0.59319	0.792939	0.139173	-0.66902	0.730102	0.139173
-3E-15	0.990268	0.139173	-3E-15	0.990268	0.139173	-0.04319	0.989326	0.139173	-0.08803	0.986348	0.139173	-0.13268	0.981339	0.139173	-0.27959	0.949978	0.139173	-0.37256	0.917512	0.139173	-0.46032	0.876777	0.139173	-0.57926	0.803171	0.139173	-0.65488	0.742811	0.139173
-3E-15	0.990268	0.139173	-3E-15	0.990268	0.139173	-0.03801	0.989538	0.139173	-0.07597	0.98735	0.139173	-0.11382	0.983705	0.139173	-0.26464	0.954252	0.139173	-0.35488	0.924495	0.139173	-0.4434	0.885452	0.139173	-0.56516	0.813158	0.139173	-0.64181	0.754127	0.139173
-3E-15	0.990268	0.139173	-3E-15	0.990268	0.139173	-0.03111	0.989779	0.139173	-0.0639	0.988204	0.139173	-0.09491	0.985709	0.139173	-0.24962	0.958291	0.139173	-0.33869	0.930548	0.139173	-0.42632	0.893801	0.139173	-0.55088	0.822897	0.139173	-0.62722	0.766309	0.139173
-3E-15	0.990268	0.139173	-3E-15	0.990268	0.139173	-0.02592	0.989929	0.139173	-0.0501	0.989	0.139173	-0.07597	0.98735	0.139173	-0.23453	0.962094	0.139173	-0.3224	0.936317	0.139173	-0.40908	0.901821	0.139173	-0.53789	0.831449	0.139173	-0.61239	0.778209	0.139173
-3E-15	0.990268	0.139173	-3E-15	0.990268	0.139173	-0.01901	0.990086	0.139173	-0.03801	0.989538	0.139173	-0.057	0.988626	0.139173	-0.21771	0.966041	0.139173	-0.30601	0.941801	0.139173	-0.3917	0.909508	0.139173	-0.5233	0.84071	0.139173	-0.59872	0.788778	0.139173
-3E-15	0.990268	0.139173	-3E-15	0.990268	0.139173	-0.0121	0.990194	0.139173	-0.02592	0.989929	0.139173	-0.03801	0.989538	0.139173	-0.20251	0.969341	0.139173	-0.28953	0.946998	0.139173	-0.37416	0.91686	0.139173	-0.50854	0.849714	0.139173	-0.58346	0.800127	0.139173
-3E-15	0.990268	0.139173	-3E-15	0.990268	0.139173	-0.00691	0.990244	0.139173	-0.0121	0.990194	0.139173	-0.00173	0.990267	0.139173	-0.18726	0.972402	0.139173	-0.27295	0.951907	0.139173	-0.35649	0.923874	0.139173	-0.49513	0.857597	0.139173	-0.56941	0.810188	0.139173
-3E-15	0.990268	0.139173	-3E-15	0.990268	0.139173	-3.36E-15	0.990268	0.139173	-3.36E-15	0.990268	0.139173	-3.36E-15	0.990268	0.139173	-0.17196	0.975224	0.139173	-0.2563	0.956526	0.139173	-0.35488	0.924495	0.139173	-0.48009	0.866108	0.139173	-0.55375	0.820969	0.139173

col 31			col 32			col 33			col 34			col 35			col 36		
-0.85499	0.499618	0.139173	-0.90744	0.396453	0.139173	-0.947	0.289526	0.139173	-0.97431	0.177062	0.139173	-0.9882	0.063904	0.139173	0.015192	0.051827	0.139173
-0.84434	0.517414	0.139173	-0.89894	0.41537	0.139173	-0.94073	0.309295	0.139173	-0.96969	0.200814	0.139173	-0.98635	0.088029	0.139173	0.010524	0.025913	0.139173
-0.83332	0.534983	0.139173	-0.89005	0.434105	0.139173	-0.93347	0.330558	0.139173	-0.96489	0.222762	0.139173	-0.98371	0.113819	0.139173	-0.99999	0	0.139173
-0.82193	0.552317	0.139173	-0.88076	0.452649	0.139173	-0.92573	0.351651	0.139173	-0.95916	0.24627	0.139173	-0.98063	0.137819	0.139173	-0.98948	0.025921	0.139173
-0.81019	0.569409	0.139173	-0.87109	0.470995	0.139173	-0.91751	0.372563	0.139173	-0.95285	0.26963	0.139173	-0.97669	0.163441	0.139173	-0.98481	0.051827	0.139173
-0.79809	0.586252	0.139173	-0.86189	0.487631	0.139173	-0.90882	0.393283	0.139173	-0.94598	0.29283	0.139173	-0.97207	0.188952	0.139173	-0.98722	0.077696	0.139173
-0.78563	0.602837	0.139173	-0.85148	0.505574	0.139173	-0.90039	0.41223	0.139173	-0.93909	0.314217	0.139173	-0.96717	0.212646	0.139173	-0.98484	0.103511	0.139173
-0.77284	0.619158	0.139173	-0.84071	0.523296	0.139173	-0.8908	0.432551	0.139173	-0.93114	0.337067	0.139173	-0.96127	0.23789	0.139173	-0.9818	0.129256	0.139173
-0.7597	0.635207	0.139173	-0.82957	0.540787	0.139173	-0.88076	0.452649	0.139173	-0.92262	0.359716	0.139173	-0.95471	0.262972	0.139173	-0.97808	0.154912	0.139173
-0.74623	0.650978	0.139173	-0.81806	0.558042	0.139173	-0.87026	0.472515	0.139173	-0.91356	0.38215	0.139173	-0.948	0.286219	0.139173	-0.97369	0.180462	0.139173
-0.73243	0.666463	0.139173	-0.80619	0.575052	0.139173	-0.85932	0.492137	0.139173	-0.90465	0.402778	0.139173	-0.94019	0.310937	0.139173	-0.96863	0.205888	0.139173
-0.71832	0.681656	0.139173	-0.79397	0.591809	0.139173	-0.84883	0.510026	0.139173	-0.89454	0.424761	0.139173	-0.93172	0.335441	0.139173	-0.96291	0.231173	0.139173
-0.70267	0.697777	0.139173	-0.7814	0.608307	0.139173	-0.83704	0.529152	0.139173	-0.8839	0.44649	0.139173	-0.92325	0.358105	0.139173	-0.95653	0.2563	0.139173
-0.6879	0.712339	0.139173	-0.76849	0.624538	0.139173	-0.82482	0.548006	0.139173	-0.87354	0.466428	0.139173	-0.91356	0.38215	0.139173	-0.94949	0.281251	0.139173
-0.67283	0.726589	0.139173	-0.75636	0.639176	0.139173	-0.81217	0.566578	0.139173	-0.86189	0.487631	0.139173	-0.90395	0.404357	0.139173	-0.9418	0.30601	0.139173
-0.65746	0.740521	0.139173	-0.74281	0.654876	0.139173	-0.79911	0.584858	0.139173	-0.84971	0.508544	0.139173	-0.89306	0.427881	0.139173	-0.93347	0.330558	0.139173
-0.64181	0.754127	0.139173	-0.72893	0.670289	0.139173	-0.78668	0.601465	0.139173	-0.83704	0.529152	0.139173	-0.88155	0.451112	0.139173	-0.92449	0.35488	0.139173
-0.62588	0.767403	0.139173	-0.71474	0.685407	0.139173	-0.77284	0.619158	0.139173	-0.82482	0.548006	0.139173	-0.87026	0.472515	0.139173	-0.91489	0.378959	0.139173
-0.[illegible]	[illegible]	[illegible]73	-0.70023	0.700225	0.139173	-0.75859	0.636532	0.139173	-0.81118	0.567994	0.139173	-0.8576	0.495134	0.139173	-0.90465	0.402778	0.139173

Appendix B

SLT Model Spreadsheet: ‘XSENSOR® Shoulder Template (v. Feb7).xls’

Summary of Output Data

Definitions:

With Curve: Forces resolved around shoulder using directional normals
No Curve: Flat sum with no curvature effects
Difference: Fz with curve/Fz no curve
Applied force: Manual input in blue cells with applied load (lb)
Expected: Applied force converted and resolved into X and Z directions

INPUT HERE

=SIN(0)
=COS(0)

	With Curve			No Curve - Sum		Applied Force (lb)	Expected	
Trial	Fx (N)	Fy (N)	Fz (N)	(N)	Difference		Fx (N)	Fz (N)
1	=Trial1!B45	0	=Trial1!C45	=Trial1!B48	=E13/D13	21.6	0	=G13*4.448222
2	=Trial2!B45	0	=Trial2!C45	=Trial2!B48	=E14/D14	21.6	0	96.138
3	=Trial3!B45	0	=Trial3!C45	=Trial3!B48	=E15/D15	21.6	0	96.138
Average	=AVERAGE(B13:B15)	=AVERAGE(C13:C15)	=AVERAGE(D13:D15)					

Diameter of shoulder	120 mm
Radius of shoulder	60 mm
Circumference of shoulder	376.991118 mm
Arc length between sensel (.25in)	12.7 mm
Degrees per mm circumference	0.95492966 deg
Degrees between sensels	12.1276067 deg

Test Area			
Row	Angle from vertical deg	X Multiplier	Z Multiplier
1	-90.95704998	-0.9998605	-0.0167029
2	-78.82944331	-0.9810548	0.19373023
3	-66.70183665	-0.9184591	0.39551606
4	-54.57422999	-0.8148672	0.57964774
5	-42.44662332	-0.6749031	0.7379064
6	-30.31901666	-0.5048142	0.86322805
7	-18.19141	-0.3121925	0.95001887
8	-6.063803332	-0.1056359	0.99440488
9	6.063803332	0.10563588	0.99440488
10	18.19141	0.31219249	0.95001887
11	30.31901666	0.50481416	0.86322805
12	42.44662332	0.67490307	0.7379064
13	54.57422999	0.81486717	0.57964774
14	66.70183665	0.91845906	0.39551606
15	78.82944331	0.98105484	0.19373023
16	90.95704998	0.9998605	-0.0167029

Template

Row	Angle from vertical deg	X Multiplier	Z Multiplier
1	-212.2331166	0.533365282	-0.845885026
2	-200.1055099	0.343750003	-0.939061199
3	-187.9779033	0.138791183	-0.990321669
4	-175.8502966	-0.07236268	-0.997378384
5	-163.72269	-0.28028659	-0.959916365
6	-151.5950833	-0.47569969	-0.879607755
7	-139.4674766	-0.64987958	-0.760037191
8	-127.33987	-0.7950516	-0.606541793
9	-115.2122633	-0.9047359	-0.425972947
10	-103.0846566	-0.97403663	-0.226390476
11	-90.95704998	-0.9998605	-0.016702896
12	-78.82944331	-0.98105484	0.19373023
13	-66.70183665	-0.91845906	0.395516061
14	-54.57422999	-0.81486717	0.579647735
15	-42.44662332	-0.67490307	0.737906396
16	-30.31901666	-0.50481416	0.863228049
17	-18.19141	-0.31219249	0.950018867
18	-6.063803332	-0.10563588	0.994404878
19	6.063803332	0.105635876	0.994404878
20	18.19141	0.312192492	0.950018867
21	30.31901666	0.50481416	0.863228049
22	42.44662332	0.674903068	0.737906396
23	54.57422999	0.814867169	0.579647735
24	66.70183665	0.91845906	0.395516061
25	78.82944331	0.98105484	0.19373023
26	90.95704998	0.999860497	-0.016702896
27	103.0846566	0.974036628	-0.226390476
28	115.2122633	0.9047359	-0.425972947
29	127.33987	0.795051604	-0.606541793
30	139.4674766	0.64987958	-0.760037191
31	151.5950833	0.475699692	-0.879607755
32	163.72269	0.28028659	-0.959916365
33	175.8502966	0.072362685	-0.997378384
34	187.9779033	-0.13879118	-0.990321669
35	200.1055099	-0.34375	-0.939061199
36	212.2331166	-0.53336528	-0.845885026

Raw	mmHg																																			
Row	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	102	76	72	70	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	86	96	103	109	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	85	89	95	99	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	92	82	90	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	83	86	82	97	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	83	85	91	94	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	88	89	102	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	75	82	76	89	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	72	82	76	87	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	86	96	80	97	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	66	84	70	89	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	60	74	66	101	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	65	77	67	95	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	66	85	66	104	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25	30	27	32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Raw Row	mmHg 1		2		3		4		5		6		7		8		9		10		11		12		13		14		15		16	
	X	Z	X	Z	X	Z	X	Z	X	Z	X	Z	X	Z	X	Z	X	Z	X	Z	X	Z	X	Z	X	Z	X	Z	X	Z	X	Z
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Subtotal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Row	17		18		19		20		21	
	X	Z	X	Z	X	Z	X	Z	X	Z
1	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0
12	-100.1	19.8	-74.6	14.7	-70.6	13.9	-68.7	13.6	0	0
13	-79.0	34.0	-88.2	38.0	-94.6	40.7	-100.1	43.1	0	0
14	-69.3	49.3	-72.5	51.6	-77.4	55.1	-80.7	57.4	0	0
15	-62.1	67.9	-55.3	60.5	-60.7	66.4	-67.5	73.8	0	0
16	-41.9	71.6	-43.4	74.2	-41.4	70.8	-49.0	83.7	0	0
17	-25.9	78.9	-26.5	80.8	-28.4	86.5	-29.3	89.3	0	0
18	-10.6	99.4	-9.3	87.5	-9.4	88.5	-10.8	101.4	0	0
19	7.9	74.6	8.7	81.5	8.0	75.6	9.4	88.5	0	0
20	22.5	68.4	25.6	77.9	23.7	72.2	27.2	82.7	0	0
21	43.4	74.2	48.5	82.9	40.4	69.1	49.0	83.7	0	0
22	44.5	48.7	56.7	62.0	47.2	51.7	60.1	65.7	0	0
23	48.9	34.8	60.3	42.9	53.8	38.3	82.3	58.5	0	0
24	59.7	25.7	70.7	30.5	61.5	26.5	87.3	37.6	0	0
25	64.7	12.8	83.4	16.5	64.7	12.8	102.0	20.1	0	0
26	25.0	-0.4	30.0	-0.5	27.0	-0.5	32.0	-0.5	0	0
27	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0	0	0
32	0	0	0	0	0	0	0	0	0	0
33	0	0	0	0	0	0	0	0	0	0
34	0	0	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0	0	0	0
36	0	0	0	0	0	0	0	0	0	0
Subtotal	-72.1	760	13.98	800.90	-56.15	767.48	43.14	899	0	0

Row	22		23		24		25		26		27		28		29		30		31		32		34		35		36	
	X	Z	X	Z	X	Z	X	Z	X	Z	X	Z	X	Z	X	Z	X	Z	X	Z	X	Z	X	Z	X	Z	X	Z
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Subtotal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Totals	X	Z
mmhg	-71.1	3226.6
Newtons	-1.53	69.384

Raw Sum	4890
Newtons	105.2

kg/msq	-967	
kg	-13.1	
Kpa	-9.48	430.18
Sensels	88	
Total Area	22	sqin
Newtons	-135	610.58
kg	-13.7	62.241
Raw Data	Newtons	

Trial 1	Average of 2 mins			
Row	Col 1	Col 2	Col 3	Col 4
1	0	0	0	0
2	0	0	0	0
3	0	0	0	0
4	0	0	0	0
5	0	0	0	0
6	0	0	0	0
7	0	0	0	0
8	0	0	0	0
9	0	0	0	0
10	0	0	0	0
11	0	0	0	0
12	0	0	0	0
13	0	0	0	0
14	0	0	0	0
15	0	0	0	0

	Col 1		Col 2		Col 3		Col 4	
Row	X	Z	X	Z	X	Z	X	Z
1	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0
Sub-total	0	0	0	0	0	0	0	0

SUM	0	N

TOTAL	X	Z	
	0	0	N

	0	0	kg
Expected	0	10	kg

samples	time (s)	sensels	persensel
10	18	1296	4E-04
41.9904	0.0429	100	

Appendix C

Final Model Spreadsheet: ‘Final XSENSOR® SLDM Template.xls’

Method of Reporting Measured vs. Expected Forces

Date:
Pack:

SLT

Load	Mass	Measured				Expected			Strap Tension	
		Fx (N)	Fy (N)	Fz (N)	Lean Angle	Fx (N)	Fy (N)	Fz (N)	Shoulder L	Shoulder R
Empty										
Low										
Medium										
Heavy										

SS

Load	Mass	Measured				Expected			Strap Tension	
		Fx (N)	Fy (N)	Fz (N)	Lean Angle	Fx (N)	Fy (N)	Fz (N)	Waist L	Waist R
Empty										
Low										
Medium										
Heavy										

Combined

Load	Mass	Measured Shoulder			Measured SLT				Expected Shoulder			Expected SLT			Strap Tension			
		Fx (N)	Fy (N)	Fz (N)	Fx (N)	Fy (N)	Fz (N)	Lean Angl	Fx (N)	Fy (N)	Fz (N)	Fx (N)	Fy (N)	Fz (N)	Shoulder L	Shoulder R	Waist L	Waist R
Empty																		
Low																		
Medium																		
Heavy																		

Combined

Load	Z Ratio SS:SL	nent at Waist (Mx) Nm
Empty	#DIV/0!	0
Low	#DIV/0!	0
Medium	#DIV/0!	0
Heavy	#DIV/0!	0

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(U) The Dynamic Biomechanical Model (DBM) requires input about pack geometry and the material property response of the load carriage suspension interface to resolve the forces acting on the body. Since there is extensive redundancy in applied forces (i.e., shoulder straps, load lifter straps, hip stabilizer straps and waist belt and skin contact pressure), it is not possible to describe the mechanical characteristics of pack components as combinations of linear and/or non linear springs and linear and/or non linear dampers unless a standardized protocol is used to determine the limit values that should be placed on specific straps in the model. The purpose of this report is to describe the common pack protocol on the Load Distribution Mannequin that will be followed when establishing these limit values for the DBM. The rationale for using the static Load Distribution Mannequin is that forces can be partitioned into upper and lower body forces, it is easier to control strap force inputs than with the Load Carriage Simulator and dynamic forces follow a similar profile to static measures expect that amplitudes and phase shifts are likely. (DBM model is calibrated for these conditions using the LC Simulator). This report describes the protocol for the baseline testing of backpacks on the Standardized Load Distribution Mannequin (SLDM). The protocol describes three different configurations: isolated shoulder, isolated waist belt and combined shoulder and waist belt.

14. KEYWORDS, DESCRIPTORS or IDENTIFIERS (Technically meaningful terms or short phrases that characterize a document and could be helpful in cataloguing the document. They should be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location may also be included. If possible keywords should be selected from a published thesaurus, e.g. Thesaurus of Engineering and Scientific Terms (TEST) and that thesaurus identified. If it is not possible to select indexing terms which are Unclassified, the classification of each should be indicated as with the title.)

(U) Load Carriage; Dynamic Biomechanical model; Skin contact pressure; Load distribution mannequin; Pressure Measurement Systems; User Manual